Grande, and whose summit is only 50 feet above the lake and 154 feet above sea level. This gap, which occupies so important a relation to the proposed canal, is the product of the familiar process of stream capture. Owing to the decided advantages possessed by the streams flowing directly to the Pacific over those flowing eastward, at first to the bay indenting the Pacific coast and afterwards to the lake, the former were able to cut backward through the divide into the drainage area of the latter and to divert their headwaters. In this way an eastward-flowing stream originally occupying the position of the Tola, the upper Rio Grande, the Guiscoyol and the Lajas was beheaded and the drainage of a large part of its basin was diverted to the Pacific. The deserted valley of this stream forms the low gap through which the canal route is located. It is so broad and level that accurate instrumental work is required to determine the actual summit of the continental divide.

Considering the origin of Lake Nicaragua, it is manifest that it must originally have extended entirely down to the point where its waters escaped through the gap in the continental divide—that is, to the present Castillo Rapids. This point, however, is now more than 30 miles down the San Juan River from the lake. The upper portion of that river meanders through an alluvial plain which becomes narrower down streams and has evidently been reclaimed from the waters of the lake by sedimentation. It is well recognized that lakes are ephemeral features, and the commonest way in which they are obliterated is by the filling at their upper ends with sediment deposited at the mouths of tributaries. In this case, however, the process is reversed. The area of the lake is being contracted chiefly by filling at its lower end. The filling is being accomplished by the tributaries entering this lower portion of the lake, many of which have been converted into tributaries of the San Juan. The present river channel does not coincide with the position of the river which formerly occupied this basin before it was drowned by the waters of the lake. Its position is dependent on the relative amounts of sediment delivered by the tributaries on either side, and it has been pushed toward the northern side of the old basin by the larger tributaries from the south, the Frio and Poco Sol. This portion of the San Juan may best be described as a *residual river channel*—that is, a broad arm of the lake has been gradually constricted by the deposition of sediment on its margin, and all that remains is the narrow river channel kept open by the current of water flowing from the lake. This hypothesis, verified by borings made in the river channel, has been of material service in so locating the canal line that all rock excavation in this portion between the lake and the Castillo Rapids should be avoided.

While the writer has no intention of touching upon the engineering features of the canal problem, it may be stated that the geologic examination of the route, including the boring, has resulted, in nearly every case, in showing that conditions are more favorable than they had previously been assumed. In the few cases in which less favorable conditions were found modifications in the plans suggested themselves by which the unfavorable conditions are avoided.

Thus the project, which has repeatedly been pronounced feasible by eminent engineers, is placed in a still stronger position by the most exacting scientific tests.

C. Willard Hayes.

U. S. Geological Survey, July, 1899.

---

*TRANSPARENCY AND OPACITY.**

One kind of opacity is due to absorption; but the lecture dealt rather with that de-

* Abstract of a lecture given by Lord Rayleigh before the Royal Institution of Great Britain.

ficiency of transparency which depends upon irregular reflexions and refractions. One of the best examples is that met with in Christiansen's experiment. Powdered glass, all from one piece and free from dirt, is placed in a bottle with parallel flat sides. In this state it is quite opaque; but if the interstices between the fragments are filled up with a liquid mixture of bisulphide of of carbon and benzole, carefully adjusted so as to be of equal refractivity with the glass, the mass becomes optically homogeneous, and therefore transparent. In consequence, however, of the different dispersive powers of the two substances, the adjustment is good for one part only of the spectrum, other parts being scattered in transmission much as if no liquid were employed, though, of course, in a less degree. The consequence is that a small source of light, backed preferably by a dark ground, is seen in its natural outlines, but strongly colored. The color depends upon the precise composition of the liquid, and further varies with the temperature, a few degrees of warmth sufficing to cause a transition from red through yellow to green.

The lecturer had long been aware that the light regularly transmitted through a stratum of 15 to 20 mm. thick was of a high degree of purity, but it was only recently that he found, to his astonishment, as the result of a more particular observation, that the range of refrangibility included was but two and a half times that embraced by the two D-lines. The poverty of general effect, when the darkness of the background is not attended to, was thus explained; for the highly monochromatic and accordingly attenuated light from the special source is then overlaid by diffused light of other colors.

More precise determinations of the range of light transmitted were subsequently effected with thinner strata of glass powder contained in cells formed of parallel glass. The cell may be placed between the prisms of the spectroscope and the object glass of the collimator. With the above-mentioned liquids a stratum 5 mm. thick transmitted, without appreciable disturbance, a range of the spectrum measured by 11.3 times the interval of the D's. In another cell of the same thickness an effort was made to reduce the difference of dispersive powers. To this end the powder was of plate glass and the liquid oil of cedar-wood adjusted with a little bisulphide of carbon. The general transparency of this cell was the highest yet observed. When it was tested upon the spectrum the range of refrangibility transmitted was estimated at 34 times the interval of the D's.

As regards the substitution of other transparent solid material for glass the choice is restricted by the presumed necessity of avoiding appreciable double refraction. Common salt is singly refracting, but attempts to use it were not successful. Opaque patches always interfered. With the idea that these might be due to included mother liquor, the salt was heated to incipient redness, but with little advantage. Transparent rock-salt artificially broken may, however, be used with good effect, but there is some difficulty in preventing the approximately rectangular fragments from arranging themselves too closely.

The principle of evanescent refraction may also be applied to the spectroscope. Some twenty years ago an instrument had been constructed upon this plan. Twelve 90° prisms of Chance's 'dense flint' were cemented in a row upon a strip of glass, and the whole was immersed in a liquid mixture of bisulphide of carbon with a little benzole. The dispersive power of the liquid exceeds that of the solid, and the difference amounts to about three-quarters of the dispersive power of Chance's 'extra dense flint.' The resolving power of the latter glass is measured by the number of centi-

meters of available thickness, if we take the power required to resolve the D-lines as unity. The compound spectroscope had an available thickness of 12 inches or 30 cm., so that its theoretical resolving power (in the yellow region of the spectrum) would be about 22. With the aid of a reflector the prism could be used twice over, and then the resolving power is doubled.

One of the objections to a stereoscope depending upon bisulphide of carbon is the sensitiveness to temperature. In the ordinary arrangement of prisms the refracting edges are vertical. If, as often happens, the upper part of a fluid prism is warmer than the lower the definition is ruined, one degree (Centigrade) of temperature making nine times as great a difference of refraction as a passage from D_1 to D_2. The objection is to a great extent obviated by so mounting the compound prism that the refracting edges are *horizontal*, which, of course, entails a horizontal slit. The disturbance due to a stratified temperature is then largely compensated by a change of focus.

In the instrument above described, the dispersive power is great—the D-lines are seen widely separated with the naked eye—but the aperture is inconveniently small ($\frac{1}{2}$-inch). In the new instrument exhibited, the prisms (supplied by Messrs. Watson) are larger, so that a line of ten prisms occupies 20 inches. Thus, while the resolving power is much greater, the dispersion is less than before.

In the course of the lecture the instrument was applied to show the duplicity of the reversed soda lines. The interval on the screen between the centers of the dark lines was about half an inch.

It is instructive to compare the action of the glass powder with that of the spectroscope. In the latter the disposition of the prisms is regular, and in passing from one edge of the beam to the other there is complete substitution of liquid for glass over the whole length. For one kind of light there is no relative retardation, and the resolving power depends upon the question of what change of wave-length is required in order that its relative retardation may be altered from zero to the quarter wave-length. All kinds of light for which the relative retardation is less than this remain mixed. In the case of the powder we have similar questions to consider. For one kind of light the medium is optically homogeneous, *i. e.*, the retardation is the same along all rays. If we now suppose the quality of the light slightly varied, the retardation is no longer precisely the same along all rays; but if the variation from the mean falls short of the quarter wave-length it is without importance, and the medium still behaves practically as if it were homogeneous. The difference between the action of the powder and that of the regular prisms in the spectroscope depends upon this, that in the latter there is complete substitution of glass for liquid along the extreme rays, while in the former the paths of all the rays lie partly through glass and partly through liquid in nearly the same proportions. The difference of retardations along various rays is thus a question of a deviation from an average.

It is true that we may imagine a relative distribution of glass and liquid that would more nearly assimilate the two cases. If, for example, the glass consisted of equal spheres resting against one another in cubic order some rays might pass entirely through glass and others entirely through liquid, and then the quarter wave-length of relative retardation would enter at the same total thickness in both cases. But such an arrangement would be highly unstable, and if the spheres be packed in close order the extreme relative retardation would be much less. The latter arrangement, for which exact results could readily be calculated, represents the glass powder more nearly than does the cubic order.

A simplified problem in which the element of chance is retained may be constructed by supposing the particles of glass replaced by thin parallel discs which are distributed entirely at random over a certain stratum. We may go further and imagine the discs limited to a particular plane. Each disc is supposed to exercise a minute retarding influence on the light which traverses it, and they are supposed to be so numerous that it is improbable that a ray can pass the plane without encountering a large number. A certain number (m) of encounters is more probable than any other, but if every ray encountered the same number of discs the retardation would be uniform and lead to no disturbance.

It is a question of probabilities to determine the chance of a prescribed number of encounters, or of a prescribed deviation from the mean. In the notation of the integral calculus the chance of the deviation from m lying between $\pm r$ is *

$$\frac{2}{\sqrt{\pi}} \int_0^\tau e^{-\tau^2} d\tau,$$

where $\tau = r / \sqrt{(2m)}$. This is equal to ·84 when $\tau = 1{\cdot}0$, or $r = \sqrt{(2m)}$; so that the chance is comparatively small of a deviation from m exceeding $\pm \sqrt{(2m)}$.

To represent the glass powder occupying a stratum of 2 cm. thick we may perhaps suppose that $m = 72$. There would thus be a moderate chance of a difference of retardations equal to, say, one-fifth of the extreme difference corresponding to a substitution of glass for liquid throughout the whole thickness. The range of wave-lengths in the light regularly transmitted by the powder would thus be about five times the range of wave-lengths still unseparated in a spectroscope of equal (2 cm.) thickness. Of course, no calculation of this kind can give more than a rough idea of the action of the powder, whose disposition, though partly a matter of chance, is also influenced by mechanical considerations; but it appears, at any rate, that the character of the light regularly transmitted by the powder is such as may reasonably be explained.

As regards the size of the grains of glass it will be seen that as great or a greater degree of purity may be obtained in a given thickness from coarse grains as from fine ones, but the light not regularly transmited is dispersed through smaller angles. Here, again, the comparison with the regularly disposed prisms of an actual spectroscope is useful.

At the close of the lecture the failure of transparency, which arises from the presence of particles, small compared to the wave-length of light was discussed. The tints of the setting sun were illustrated by passing the light from the electric lamp through a liquid in which a precipitate of sulphur was slowly forming.* The lecturer gave reasons for his opinion that the blue of the sky is not wholly, or even principally, due to particles of foreign matter. The molecules of air themselves are competent to disperse a light not greatly inferior in brightness to that which we receive from the sky.

R.

* See *Phil. Mag.* 1899, Vol. XLVII., p. 251.

* Op. cit., 1881, Vol. XII., 96.

DISTRIBUTION OF THE KEEWATIN IN MINNESOTA.

IN Minnesota the lithological characters of that part of the Algonkian known as Lower Huronian or Keewatin are necessary in the recognition of the stratigraphic subdivisions of geographically separated localities. The Keewatin carries the first clearly defined sediments of this portion of the globe. Often the clastic origin of the rocks has been so completely obliterated by alteration due largely to dynamic metamorphism that it is difficult to distinguish them from their associates. At the bottom of the series is usually a quartzite which is locally con-